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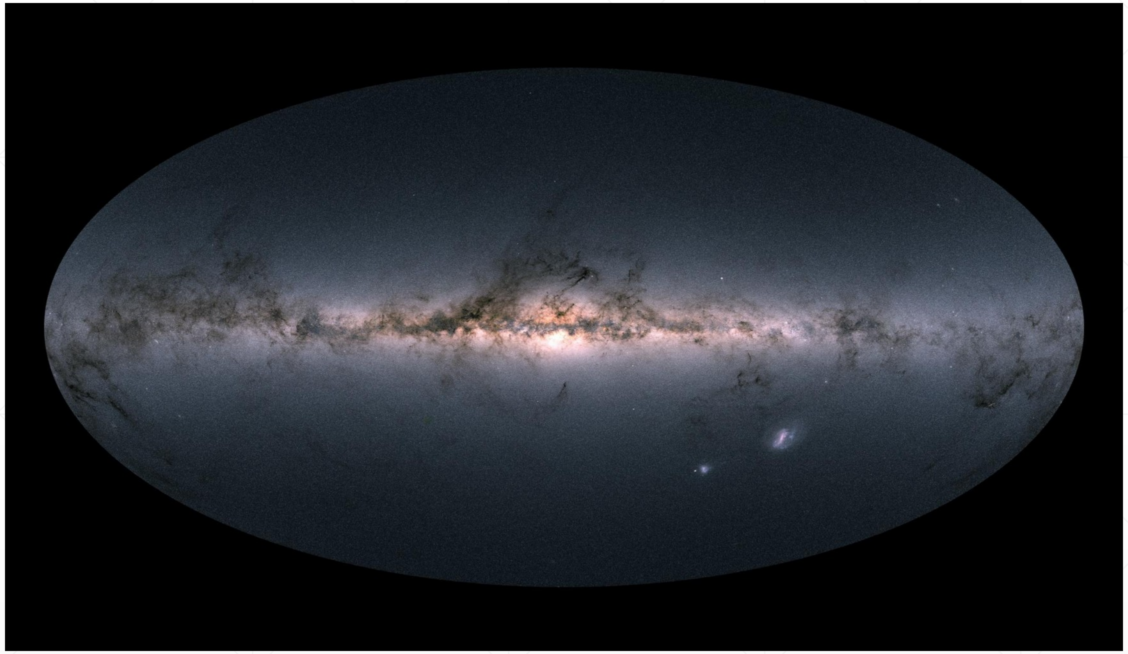
Polarimetric Studies of Galaxies

7th IDPASC/LIP PhD Student Workshop

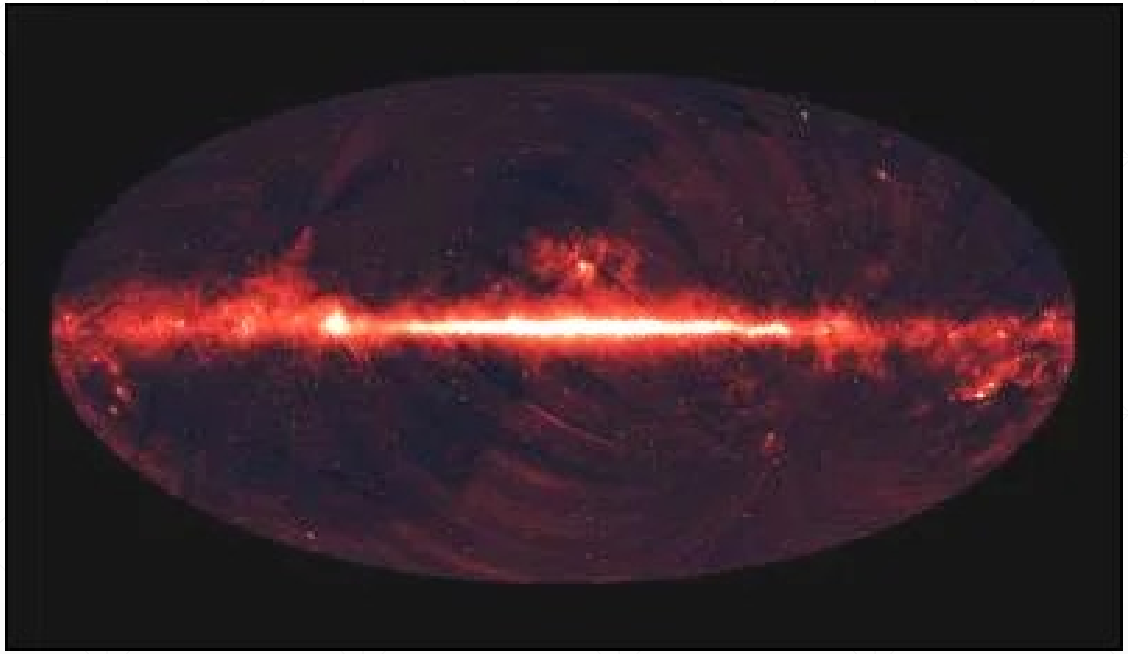
João Rino Silvestre, 07-07-2022
joao.silvestre@tecnico.ulisboa.pt

Advisors:
Santiago González Gaitán
Ana Maria Mourão

Dust in the Interstellar Medium

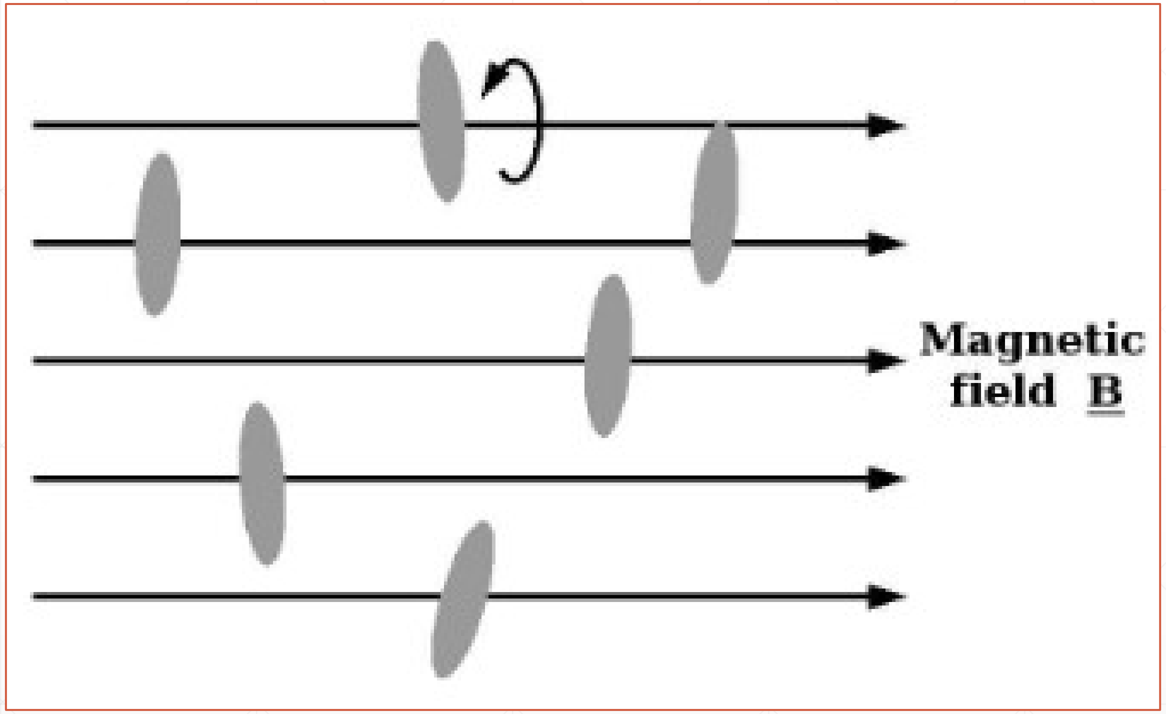


Optical map of the Milky Way (ESA/Gaia/DPAC)

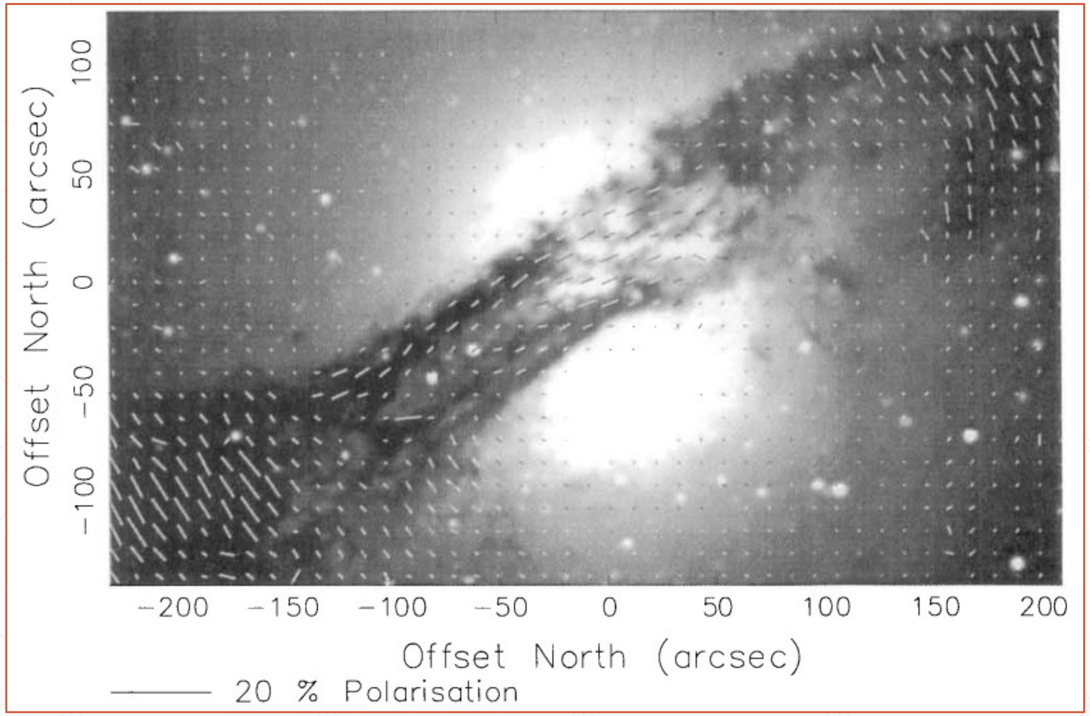


Infrared map of the Milky Way (JAXA)

Dust in the Interstellar Medium

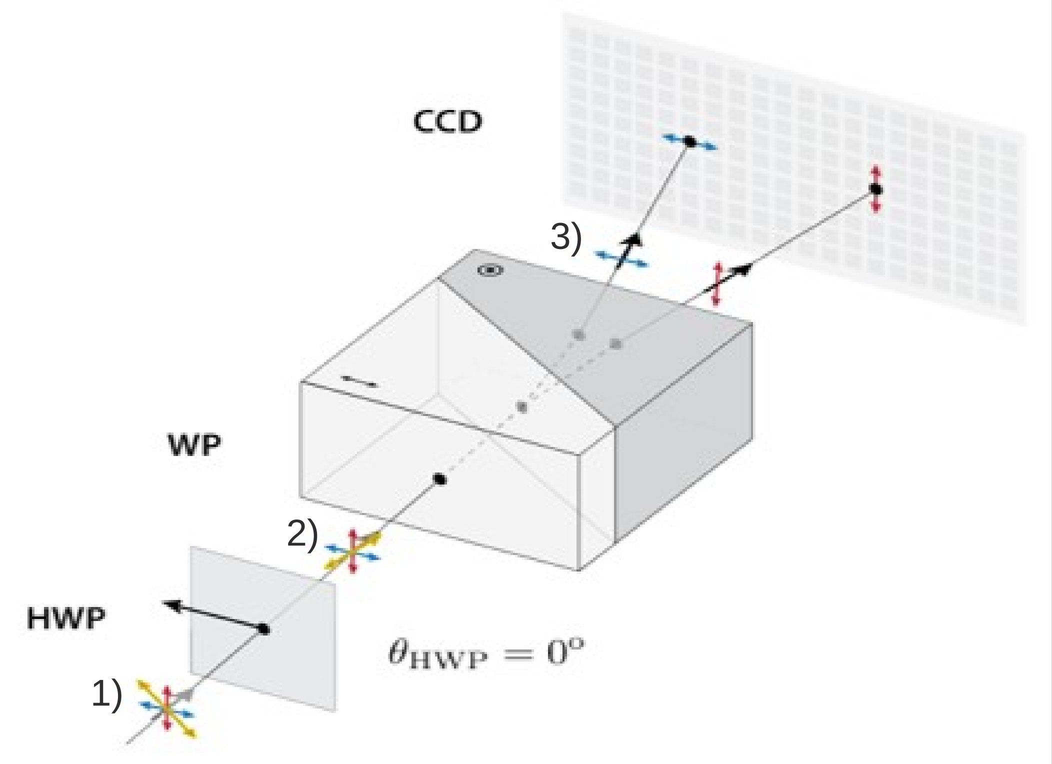


Non-spherical dust grains will tend to align their short axis with the direction of the magnetic field (by TBD).

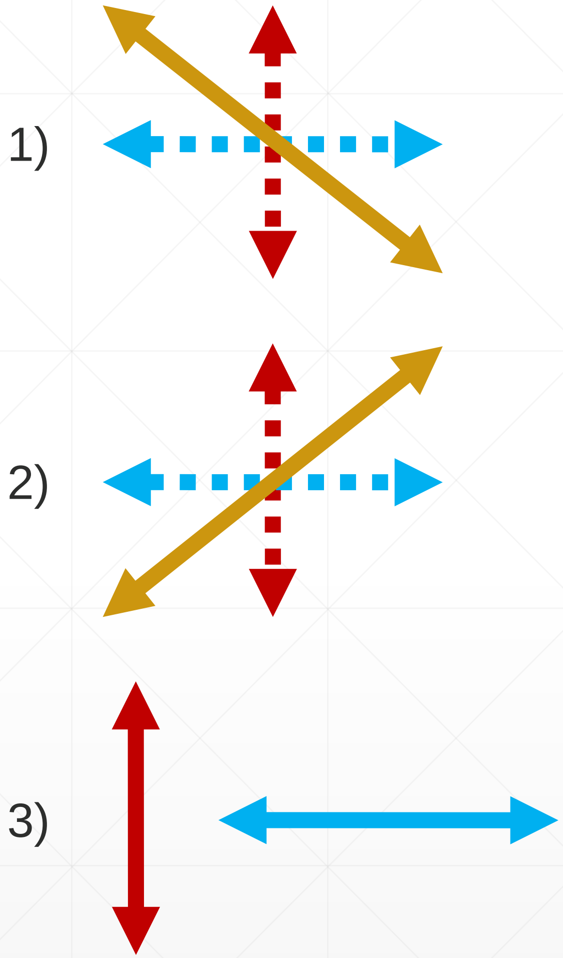


V-band polarization map superposed on a greyscale image of NGC 5128. There is significant polarization throughout the dust lane (by Scarrott et al. 1996).

Dual-Beam Polarimetry



Schematic representation of the effect of a Half-Wave Plate (HWP) and a Wollaston Prism (WP) on a lightwave (image adapted from González-Gaitán, Mourão et al. 2020).

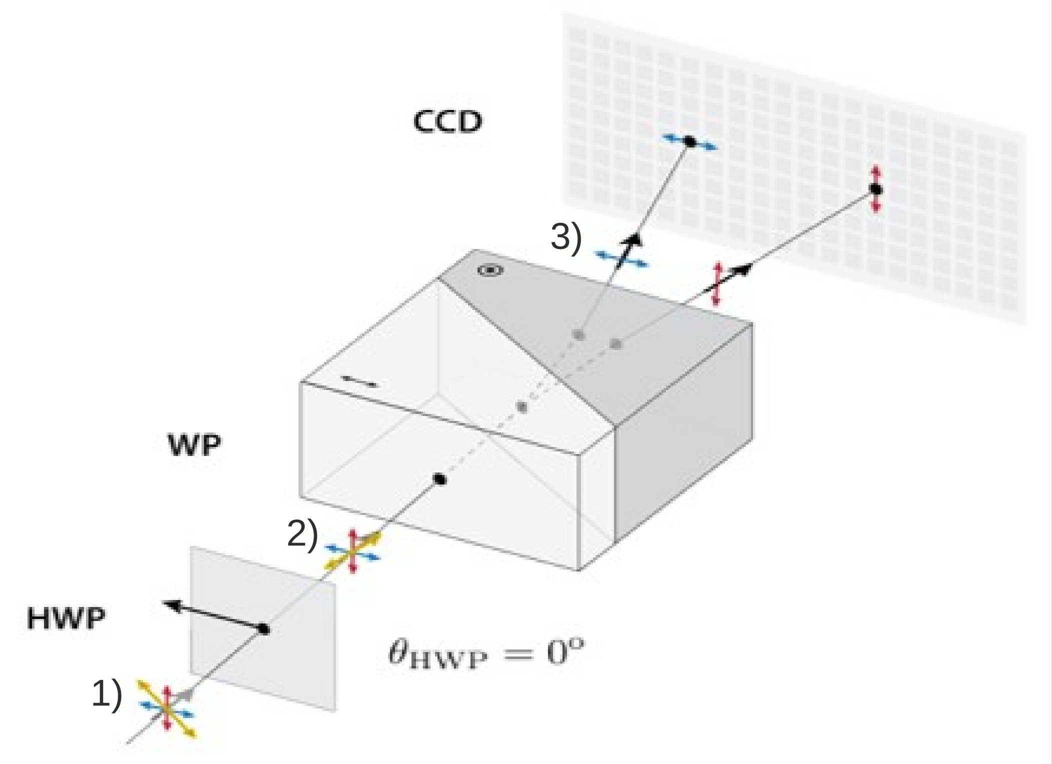


Light polarization vector, in yellow. Projections in red and blue.

Light polarization vector after being rotated by HWP, in yellow. Projections red and blue.

Ordinary and extraordinary, red and blue, beams after the polarization vector components are spatially split by the WP.

Dual-Beam Polarimetry



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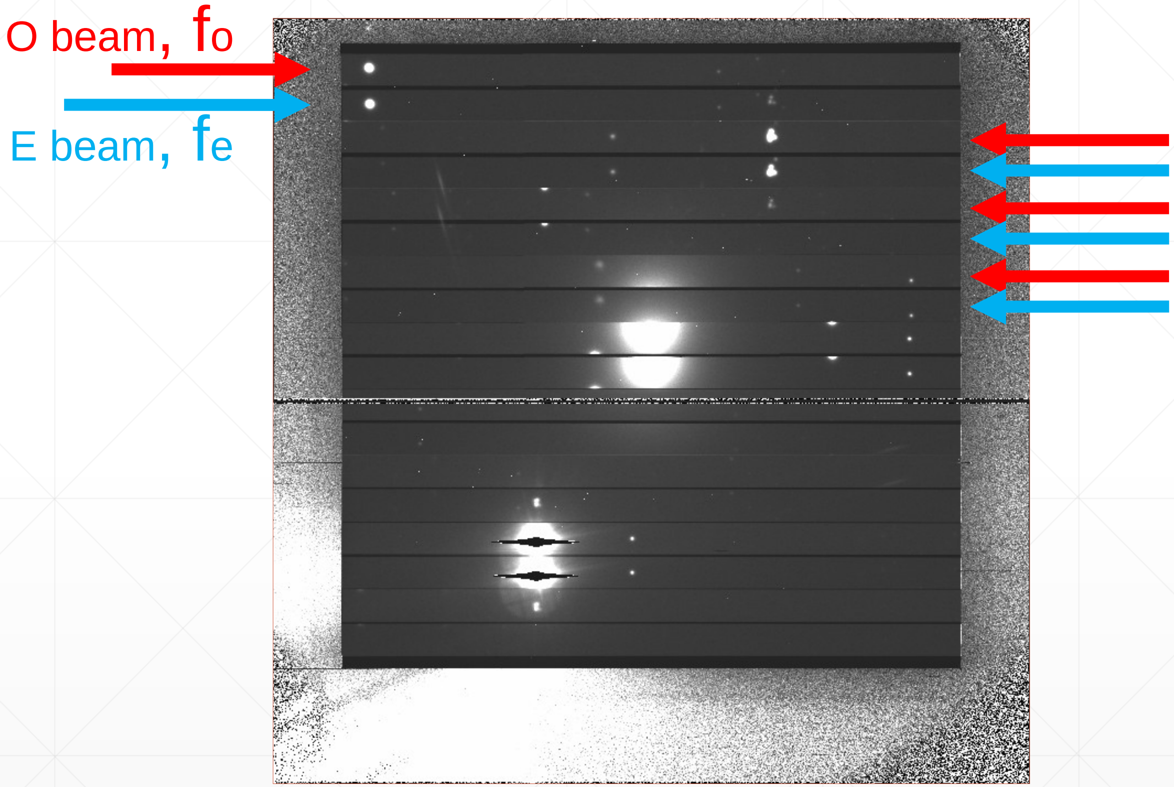
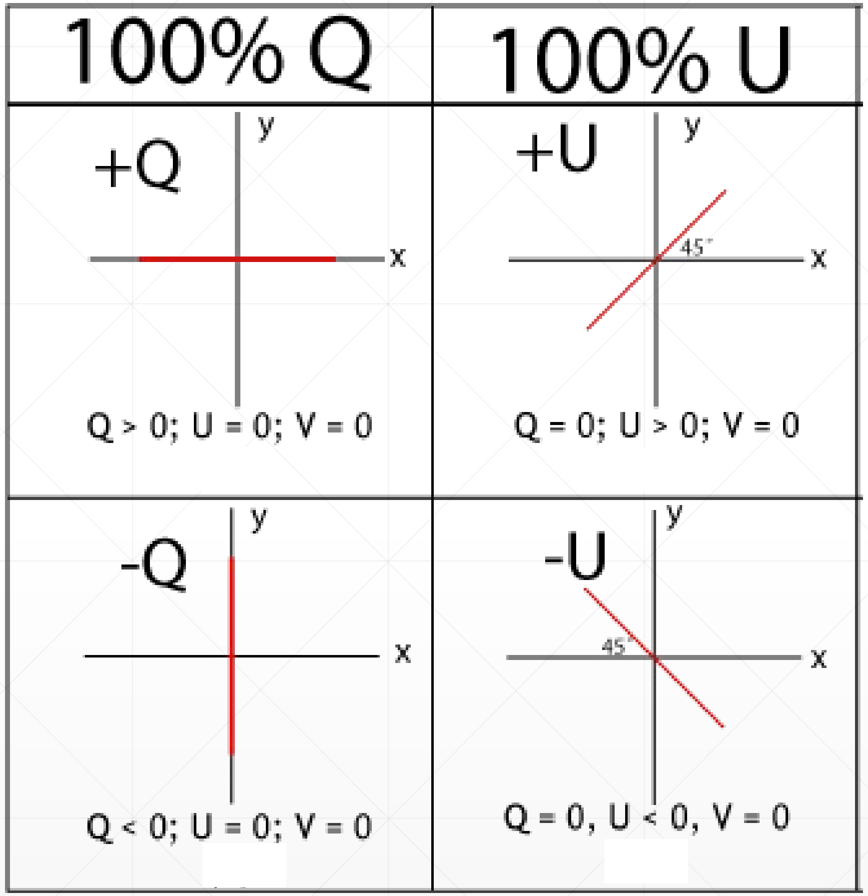


Example of polarimetric image from FORS2. NGC1404, B band filter, HWP at 0º.

Stokes Parameters for Linear Polarization



Projection of Stokes parameters Q and U into XY referential (by [Dan Moulton, CC BY-SA 3.0](#)).

$$P = \sqrt{\bar{Q}^2 + \bar{U}^2} \qquad \chi = \frac{1}{2}\arctan\frac{\bar{U}}{\bar{Q}}$$

Formulation of the polarization degree, P, and the polarization angle, , as functions of the Stokes parameters Q and U (valid when light is linearly polarized).

Calculating Q and U

- The difference method (Patat & Romaniello, 2006)

$$F_i \equiv \frac{f_o^i - f_e^i}{f_o^i + f_e^i} \qquad \bar{Q} = \frac{2}{N}\sum_{i=0}^{N-1} F_i \cos\frac{\pi}{2}i \qquad \bar{U} = \frac{2}{N}\sum_{i=0}^{N-1} F_i \sin\frac{\pi}{2}i$$

- The ratio method (Bagnulo et al., 2009)

$$R_i \equiv \frac{f_o^i}{f_e^i} \qquad \bar{Q} = \frac{\sqrt{\frac{R_0}{R_2}} - 1}{\sqrt{\frac{R_0}{R_2}} + 1} \qquad \bar{U} = \frac{\sqrt{\frac{R_1}{R_3}} - 1}{\sqrt{\frac{R_1}{R_3}} + 1}$$

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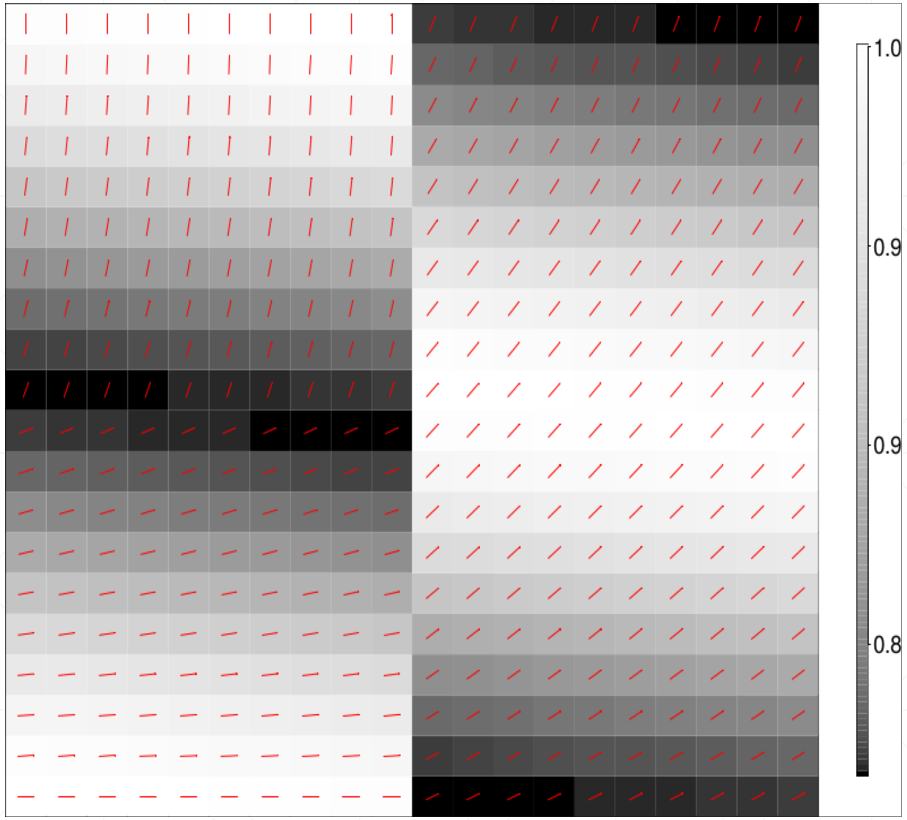
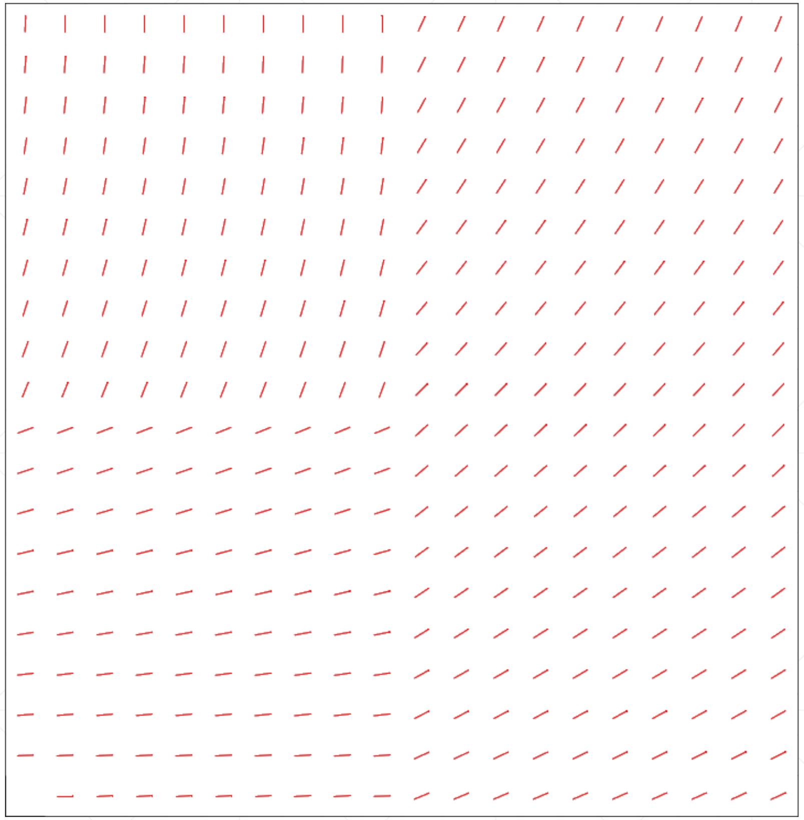
No flats needed!

No need to think about polarization flats!

Calculating Q and U
Simulation



Estimation of simulated light field using the difference method after doing FLAT corrections (paper in preparation).



Estimation of simulated light field using the ratio method without FLAT correction (paper in preparation).

Other Corrections

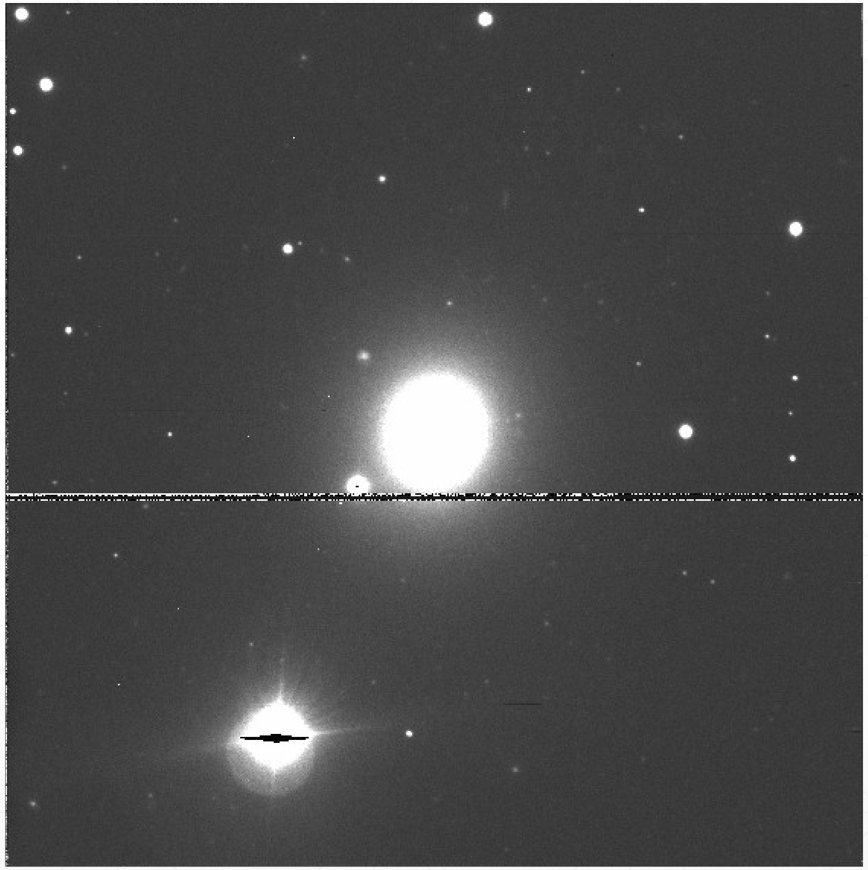
- Beam alignment considering wavelength dependent beam spread (González-Gaitán, Mourão et al 2019)

- Instrumental polarization pattern (González-Gaitán, Mourão et al 2019)

- Background polarization (sky)
  1)Mask all sources → Calculate background polarization

- Foreground polarization (Milky Way)
  1)Mask only point sources → Calculate background polarization
  2)Subtract background from data
  3)Extract point sources → Calculate median polarization

Example application



NGC1404, host galaxy for two type Ia SNe, SN2007on and SN2011iv. Photometry in B band.

Polarization field for NGC1404 in B band without corrections.

Final Remarks

- Calibration and correction techniques for polarimetric imaging
  - → new reduction pipeline for FORS2-IPOL data, almost ready
  - → one paper in preparation (early stage)

- Emulating radiative transfer
  - → Rino-Silvestre, González-Gaitán et al 2022, submitted
  - → Smole, Rino-Silvestre et al 2022, in preparation (final stage)
  - → Extension to other applications, pending